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THE NEED AND VALUE OF WATER QUALITY CRITERIA WITH SPECIAL REFERENCE TO AQUATIC LIFE

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THE NEED AND VALUE OF WATER QUALITY CRITERIA WITH SPECIAL REFERENCE TO AQUATIC LIFE

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Introduction

Our usable supply of good fresh water, like our timber and mineral supply, is exhaustible. Due to an extensive educational campaign, it has been recognized for some years that our timber supplies are being rapidly depleted and that good forest management is essential if we are to have adequate supplies in the future. The need for the wise use and management of another of our basic resources, the soil, is also being recognized. However, another of our basic resources, water, has been so abundant in some areas that we have failed to recognize its great intrinsic value and the necessity for adequate and permanent fresh water supplies of the quality required for the various desired uses. Until very recently, few of us thought of the source of our drinking water, the permanence of the supply or its future adequacy for an increasing population and industry. There is a growing per capita use of water in this country. However, much is wasted as we let the tap drip, leave the sprinkler running until water runs down the gutter, or flood the land for irrigation until water collects in pools in low places. Such practices are not only wasteful but detrimental.

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16. Abstracts The need and value of establishing water quality criteria to maintain or restore the suitability of our waters is analyzed. The various uses of water are classified into eight catagories: 1) domestic and municipal; 2)industrial; 3) agricultural; 4) aquacultural; 5) recreational; 6) aesthetic; 7) navigational and 8) power. Each are briefly discussed, but emphasis is placed on water quality criteria for aquatic life.

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Other practices also have undesirable effects on our total water supply. Not too long ago the disposal of domestic waste was a personal problem and often was solved simply by pitching it out the window or door. In the cities such practices created a hazard for anyone using the streets and odors were a constant reminder of the problem. With the development of sewers and the water carriage of wastes, the problem became less apparent. When domestic wastes are mixed in underground sewers they become impersonal and most people do not assume responsibility for them. The easiest solution is to discharge the sewers below town, out of sight and out of mind but in the neighbors drinking water. We wouldn't think of dumping our garbage on the neighbors front lawn but putting our domestic wastes into his drinking water does not seem to carry a social stigma.

Such attitudes have had a long period of development. To the early settlers our water supplies appeared to be inexhaustible. It was only natural, therefore, that they should use the streams to carry away wastes and unwanted materials even though these streams also often furnished their drinking water and were an important source of food. When population was sparce it seemed reasonable to assume that our streams could assimilate all our wastes and that their use for such purposes was economical and in the best interest of the community. These attitudes have persisted to the present time, at least in the minds of some. Until quite recently many felt that we could dedicate many of our streams to the carrying of wastes and that we could look forward to pollution becoming more widespread and severe. Many felt no particular concern over such developments as they did not foresee that

our streams would have to be cleaned up in order to assure an adequate water supply for our many future uses. In our headlong rush for "the better life", a greater population and so-called progress, we have not always considered even the short-term let alone the long-term effects of our activities on our surroundings and on ourselves. With our rapid growth a snowballing process has developed; as our population and industry expand we need more and more good water, while at the same time the wastes from our expanding activities are rendering more and more of our waters unfit for many uses.

For many years the conservationists have been pleading for the protection of our water resources, but it has been only within recent years that there has been a general awakening, a better understanding of the situation and a realization that water shortages can develop even in areas which were well supplied with fresh water. It is now agreed that our water resources are exhaustible, that short supplies may limit growth in many areas and that attention must be directed toward the conservation of our water resources. Public interest in water resources has been aroused and many new boards, committees and agencies are coming into being for the survey, evaluation and management of water resources. Those who have studied our water resources problem are agreed that we must use our supplies wisely if they are to serve the needs of all the people.

Our fresh-water resources are derived from rainfall and cannot be significantly increased by any known economically-feasible method. Ways to augment water supplies are being explored by the federal government. Several universities have research projects in this field and it

is the concensus that methods will be developed for the economical conversion of sea water to fresh water. In coastal areas, fresh-water supplies can be augmented by the conversion of sea water, but such practices are not generally feasible for inland areas because of the cost of transportation and the immense quantities needed.

The best means for increasing our inland fresh-water resources is to use the water over and over again. The greatest obstacle to such reuse is water pollution which has rendered reuse of many of our waters difficult and costly. Pollution must be controlled if we are to have adequate water supplies for the future. If our waters are to be effectively and efficiently used and reused for a variety of purposes, each user must return his process or waste water to the source in a condition suitable for other desired uses. To do this it is essential that the quality of water required for each of the desired uses be definitely known. We do not have this knowledge at present. Such knowledge is a prerequisite for water reuse. Thus, in maintaining or restoring the suitability of our waters for selected uses our first task is the determination of the water quality characteristics which are required for each use. Definite criteria of water quality for each of the principal water uses must be set up before we can effectively treat waste waters to assure their suitability and that of the receiving water for other specific uses. We must know our objectives, that is, the water quality which is needed, before we can intelligently and effectively abate pollution and reuse our water resources. In fact, criteria are essential if we are to determine objectively where pollution exists,

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measure its severity, or evaluate control measures. Such criteria are the keys to effective pollution abatement and efficient water use and reuse.

The various uses of water may be roughly classified under eight categories: (A) Domestic and municipal; (B) Industrial; (C) Agricultural; (D) Aquacultural; (E) Recreational; (F) Aesthetic; (G) Navigational and (H) Power. Waste disposal has not been listed as a use of water resources since all wastes result from the eight main uses listed above.

Wastes resulting from each of these uses are, in part, characteristic of each. Municipal or domestic wastes are largely organic and their utilization by bacteria and other microorganisms in the water may produce severe oxygen depletion. Industrial wastes may have great oxygen demands; they may be toxic to aquatic and other organisms; they may increase temperatures, produce turbidity and add settleable solids; they may add radioactivity; or they may taint the flesh of aquatic organisms. Formerly, agricultural wastes consisted largely of silt and other materials washed into streams and other waters as a result of land erosion. Recently, however, the new synthetic organic pesticides are being so widely and extensively used for the control of crop, garden and forest pests that they are becoming pollutants. Return irrigation waters can create problems as they may contain large amounts of dissolved solids which are undesirable. In addition, these waters are usually warm and may contain materials such as pesticides in concentrations that are harmful to aquatic life. Aquacultural wastes are chiefly organic, arising from the processing of

fishery products, from hatcheries and from the activities of fisherman. Recreational and aesthetic uses of our waters produce only a few harmful waste products, principally sewage and wastes from motor boats. Wastes from navigational uses are largely domestic sewage, oil and motor exhausts and spills of material being transported. Power generation may add large quantities of hot water or, if the power is produced by water, may result in decreases in dissolved oxygen and changes in temperature or character of the water due to impoundment.

Although some data are available on the quality of water required for each of the eight major water uses, a great deal remains to be learned. We are in need of information on the long-term effects of certain trace elements found in drinking water and on the maximum safe levels of heavy metals and other materials when consumed over long periods. Information is greatly needed on the effects of the ingestion over extended periods of the various pesticides which may occur in water. Knowledge of the toxic effects of a variety of materials on plants and concentrations which are not harmful under conditions of continuous exposure is needed for the establishment of quality criteria for irrigation water. With the reuse of water, quality criteria for water used in industrial operations will become increasingly important. A knowledge of the water quality requirements of aquatic populations is basic for the protection of aquatic life and the effective abatement of pollution. These criteria are our main topic for discussion.

Water Quality Criteria for Aquatic Life

The basic purpose of water quality criteria for aquatic life is to restore and maintain environmental conditions that are essential for

the survival, growth, reproduction and general well-being of the important aquatic organisms. Thus, a knowledge of these environmental conditions must precede the establishment of such criteria.

Basic Principles for the Establishment of Water Quality Criteria

In determining environmental requirements of aquatic organisms and in formulating water quality criteria, it must be constantly borne in mind that average environmental conditions are not necessarily a measure of a suitable environment. In fact, the average can be very misleading. It is the extremes of environmental conditions that govern. Extremes of even short duration can determine whether or not a species will be present in a certain area. If the water of a stream reaches temperatures that are lethal to trout on one day in the year, that stream will not be a trout stream even though conditions may be satisfactory every other day of the year. Good pools and cover, abundant spawning areas and food, and suitable chemical conditions in the water supply will be of no avail for the maintenance of a natural population if lethal temperatures occur.

In ascertaining environmental requirements which are to serve as the basis for water quality criteria the researcher is determining specifications which must be met to provide water of a quality which will meet the need for which it is intended. In setting water quality criteria for a specific use, the research scientist must not be influenced by economic or other similar considerations. His task

is to establish the quality of water which is required for a specific use. This he must do if the water is to serve that purpose. To do otherwise would make his entire effort a waste. In the implementation of water quality criteria for aquatic life the economics of the situation are taken into consideration when the water pollution control board or other enforcement agency decides what use or uses shall be given preference in a given stream or area. It should also be remembered that economic considerations, though important, are not always paramount. Public preference is a potent influence in determining pollution control programs.

In the investigations for the collection of data on the environmental requirements of aquatic life which are to serve as the basis of criteria for the restoration or maintenance of a suitable habitat, conditions as they exist in our waters must be taken into consideration. Levels or concentrations that can be tolerated for short periods should be determined. Such information would indicate; levels which can be tolerated for infrequent or short period discharges, levels satisfactory for the passage of migrating fishes, and the possible effects of spills. In the determination of environmental requirements and satisfactory levels for materials added to the water, it must be recognized that mere survival or the ability to resist death for a time does not indicate a satisfactory environment. Also it should be realized that at certain stages in their life history most organisms are more sensitive to toxicants and require more favorable environmental conditions. The chain of life is no stronger than its weakest component. Further, environmental conditions must be safe or favorable under conditions of continuous

exposure. They must be conducive to the survival, growth, reproduction, the general well-being and the production of a crop. Levels or concentrations at which adults may survive for prolonged periods may be entirely unsatisfactory for the survival of the species. Conditions also must be favorable for the food chain organisms if a species is to prosper.

Need and Value of Water Quality Criteria

Carefully formulated and well documented water quality criteria for aquatic life are essential for resolving our water pollution problems. Such criteria will be beneficial in a number of ways. They will define the objectives of a pollution control program. Well-defined objectives will contribute to a more favorable public opinion and will aid in securing public support for control programs. Water quality criteria will indicate concentrations and conditions that cause fish kills, limit growth, interfere with production of a crop, or produce nuisance organisms, and thus will aid in eliminating these conditions. They will provide information to conservationists and other interested groups regarding conditions that must be attained in order to restore and maintain our aquatic resources.

Such criteria will help industry as they will clearly define the conditions that must be met. Industry will be better able to select the best sites for new or expanded facilities and can make long-term plans for waste treatment. These criteria will indicate allowable concentrations of wastes and minimum or maximum levels safe for short-term, long-term, and continuous exposures, and thus enable industrialists to design adequate waste treatment facilities at the time of construction.

If adequately documented and tested, such criteria probably would be widely accepted by the states. This would lead to more uniform regulations and would prevent industrial developers from using the desire of communities for industrialization to secure concessions in waste treatment at the expense of the aquatic resource. Water quality criteria for aquatic life could be of definite assistance also in the prosecution of pollution cases, as they would provide well documented data on toxic concentrations and levels which are required for the maintenance of the biota. Such data would eliminate arguments as to what is toxic or harmful and would expedite decisions as to whether or not pollution exists. In this manner they would be effective in the restoration or maintenance of the aquatic biota through pollution abatement.

Setting Water Quality Criteria

Many of those who have waste disposal problems feel that it would be desirable to have a list of potential toxicants, such as arsenic, barium, boron, cadmium, chromium, copper, etc., with allowable concentrations for each expressed as p.p.m. Such a waste disposal "cookbook" would have certain advantages. It would be clear-cut and simple, it could be routinely used by inexperienced men with no special knowledge of toxicity problems or the requirements of aquatic life; it would not require a detailed analysis of the problem, and when allowable levels were met those discharging wastes would be absolved from further responsibility. Such an approach however is impracticable for several reasons. Good chemical analytical procedures are not now available for

all materials when they are mixed together at extremely small concentratins in water. Many of the analytical procedures which are available are not sensitive enough to detect toxicants at the extremely low levels at which they are toxic; i.e., a few parts per billion or a fraction of a part per billion. Most wastes are complex mixtures of substances and, since toxicities are not always additive, the toxicity of such wastes cannot be determined by simply totalling the toxicity of known components of the waste. Further, there are interactions between the components and there may be synergistic or antagonistic actions. The toxicity of many wastes is significantly influenced by the quality of the receiving water. Among the factors influencing toxicity of a waste are temperature, DO, CO_2, pH, hardness and other materials which are in solution (1). Toxic materials are generally more rapidly toxic at higher temperatures and organisms are less resistant to toxicants at low dissolved oxygen or high CO_2 concentrations (2). The pH of a receiving water can be a governing factor in toxicity. Ammonia wastes can rapidly become more toxic as the pH increases above 8.2 (3). The heavy metals and certain other materials are more toxic at low pH values and are much more toxic in soft water than they are in hard water (4). The toxicity of beryllium and uranium to test fish was found to be 60 to 80 times greater in soft water than in hard water (5). With a nickel cyanide complex a drop in pH value of 1.5 units resulted in more than a thousand-fold increase in toxicity to the test fish (6). For application over wide areas such standards would have to specify levels safe for the most sensitive species, under the water quality conditions that render the waste materials most toxic. Thus, a

company discharging copper wastes into a hard water stream would be required to treat the wastes to the same extent as one on a soft water stream even though the safe level of concentration of the material in the effluent entering the hard water stream might be 25 times that in the soft water stream.

Numerical criteria for application over wide areas should not be set for complex wastes and for those materials whose toxicity is significantly affected by the quality of the receiving water. Criteria for such wastes must be arrived at through a "tailor-made approach"; that is, their toxicity to resident species must be determined at each location. It is hoped that safe levels can be determined through the use of application factors with the results of short-term bioassays which evaluate the effects of water quality on the waste. The application factor for each particular kind of industrial waste would be determined by detailed investigations including long-term bioassays, physiological, histological, histochemical and other studies, to determine levels of the wastes that are safe under conditions of continuous exposure in waters of selected quality. These factors then would be used with TL_m values obtained from short-term bioassays that use for dilution, water taken from the receiving stream at the point at which the wastes are to be added. These tests would be carried out to evaluate the effects of that particular water on the waste under consideration, and they would evaluate most of the effects of the quality of the receiving water. It is hoped that some procedures of this nature can be developed for indicating safe levels of a particular waste in waters of different quality.

It is believed that numerical criteria which will be applicable over wide areas can be set for such environmental factors as DO, temperature, CO_2, and pH, and for those materials the toxicity of which is not significantly influenced by the quality of the receiving water. The synthetic organic pesticides are important members of this latter group.

Meeting the Present Problem

While considerable data are available on the environmental requirements of aquatic life and the toxicity of certain materials, much remains to be learned. There are many materials and wastes for which we do not know the safe concentrations in different types of waters for either short or long-term exposures. Further, the rate of production of new materials, especially petro-chemicals and synthetic organic materials, is steadily increasing. The determination of the effects of these materials on the aquatic biota is a continuing task which will not be completed in the near future. If we delay until we have all the answers, the setting of water quality criteria will be far in the future and may never be accomplished. It is imperative, therefore, that we use the knowledge we now have to set up tentative criteria that can be modified in the future on the basis of new findings. In this way it may be possible to save much of our aquatic resources that might otherwise be destroyed.

Summary and Conclusions

Water is one of our most important basic resources. It is now generally recognized that our fresh-water supplies are definitely limited,

that they cannot be increased effectively by any known economically feasible method, that water shortages will develop in the future, and that we must reuse our water extensively if our supplies are to meet future demands. Effective reuse of water requires definite knowledge of the quality of water required for each use and adequate water quality criteria to insure such quality. Water quality criteria for the protection of aquatic life are urgently needed since water pollution is a principal cause of unfavorable environmental conditions in our fresh, marine, and estuarial waters. Pollution control is a necessity and must be given the highest priority if we are to restore, maintain and develop our aquatic resources. The first step in the program is research to determine the environmental conditions which are required for the survival, growth, reproduction, and general well-being of the important members of the aquatic biota. A knowledge of these requirements is basic to the setting of water quality criteria to insure their continued well-being.

In setting water quality criteria it is the extremes of environmental conditions that must be delineated because they determine the survival of an organism and the suitability of an environment. For the production of adequate crops the ranges of most favorable conditions should be defined also. While criteria are needed to indicate safe levels for short exposure periods, stress should be laid on the determination of the levels of conditions which are not harmful under conditions of continuous exposure and which are conducive to the survival of the species. Criteria also are essential for maintaining conditions favorable to the organisms in the food chain.

Water quality criteria based on adequate and carefully formulated data will be of great value in the restoration, protection and production of aquatic resources. Such criteria will define the objectives of pollution control and waste treatment, promote uniform regulations, acquaint the public with the problems and basic aims so that public opinion can be an effective force in pollution abatement, and define pollution so that it can be more readily demonstrated in the courts.

Water is the dominant habitat on earth. It supports a great assemblage of aquatic life that provides a high protein, low fat, rich mineral food on which we may have to depend more and more in the future. Much of our recreation is dependent on aquatic resources. These resources are well worth our best and most earnest efforts for their protection, restoration, and wise use.

A survey of our efforts in the field of water pollution during the past 50 years shows a lack of clear-cut objectives and a well defined plan and demonstrates the need for a better and more effective approach to the problem. In meeting our water resource problems we must be guided by past events, recognize clearly our present needs, and plan effectively for the future.

References

1 - Critical review of literature on the toxicity of industrial wastes their components to fish. I. Alkalies, acids, and inorganic gases. Peter Doudoroff and Max Katz. Sewage and Industrial Wastes, Vol. 22, No. 11, pp. 1432-58 (1950)

2 - Biological observations and toxicity bioassays in the control of industrial waste disposal. Peter Doudoroff. Proc. of 6th Industrial Waste Conference, Purdue University Engineering Bulletin, Series 76, Vol. 35, No. 6, pp. 88-104. (Nov. 1951)

3 - Applications of biological research for the control of industrial wastes. Clarence M. Tarzwell and Peter Doudoroff. Proc. of the National Task Committee on Industrial Wastes, June 3 - 4, 1952.

4 - Critical review of literature on the toxicity of industrial wastes and their components to fish. II. The metals as salts. Peter Doudoroff and Max Katz. Sewage and Industrial Wastes, Vol 25, No. 7, pp. 802-839 (July 1953)

5 - The toxicity of some of the less common metals to fishes. C. M. Tarzwell and C. Henderson. Seminar sponsored by AEC and PHS, Dec. 6 - 9, 1955. (October 1956) Industrial Wastes, Vol. 5, No. 1, pp. 286-289. (Feb. 1960)

6 - Some experiments on the toxicity of complex cyanides to fish. Peter Doudoroff. Sewage and Industrial Wastes, Vol. 28, No. 8, pp. 1020-40. (Aug. 1956)